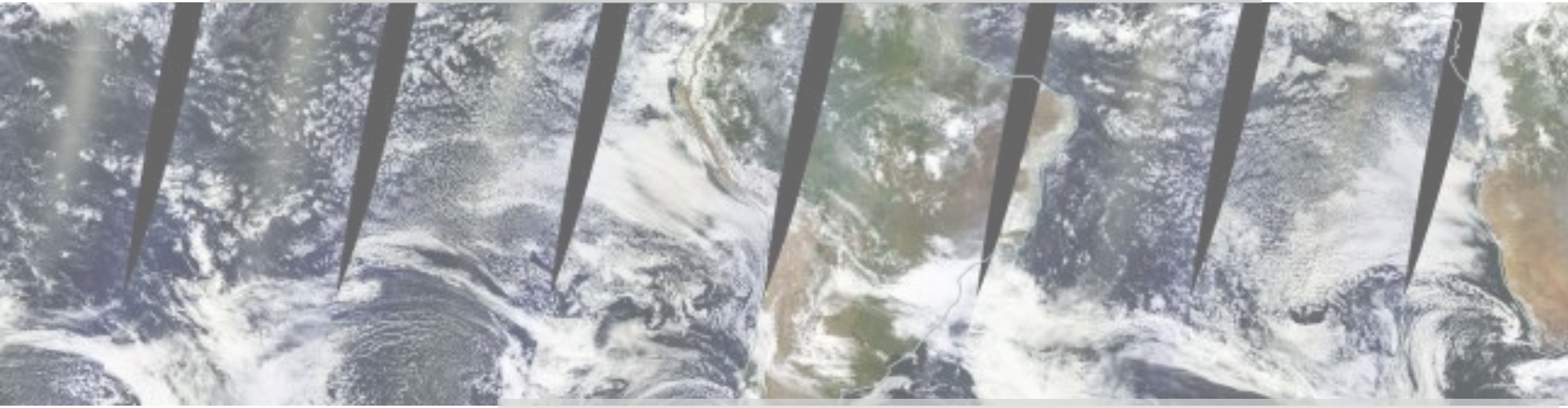
Coupled Climate Model SST Biases in the Eastern Tropical Atlantic and Pacific Oceans



Eastern Tropical Oceans Synthesis US CLIVAR Working Group

WG Objectives include identifying sources for the tropical SST biases, and the remote impact of the biases

http://www.usclivar.org/working-groups/etos

US CLIVAR

Climate Variability and Predictability Program

Home About Groups and Teams US AMOC Publications Science Meetings Calendar Contact

Eastern Tropical Oceans Synthesis Working Group

The US CLIVAR Eastern Tropical Oceans Synthesis (ETOS) Working Group (WG) was formed in 2012.

Their scientific objectives include:

- Promote collaboration between observationalists and modelers, and atmospheric scientists and oceanographers, active in the southeast oceanic basins.
- Coordinate a model assessment of surface flux errors for the equatorial Atlantic, mining all available observations.
- Identify recent model improvements and common and persistent model errors both, CMIP5 and higher-resolution coupled models.
- Provide recommendations of cases for community simulation and evaluation using eddy-permitting ocean models, sharing specified model conditions and output datasets.

The WG is identifying and assembling satellite, buoy and research cruise datasets and assembling plots of readily available CMIP3 and CMIP5 simulations for annual and seasonal-mean values of SST, cloud cover, surface winds, thermocline depth for a climatological time period beginning ~1950 or 1980 up to 2012.

ETOS WORKING GROUP MENU

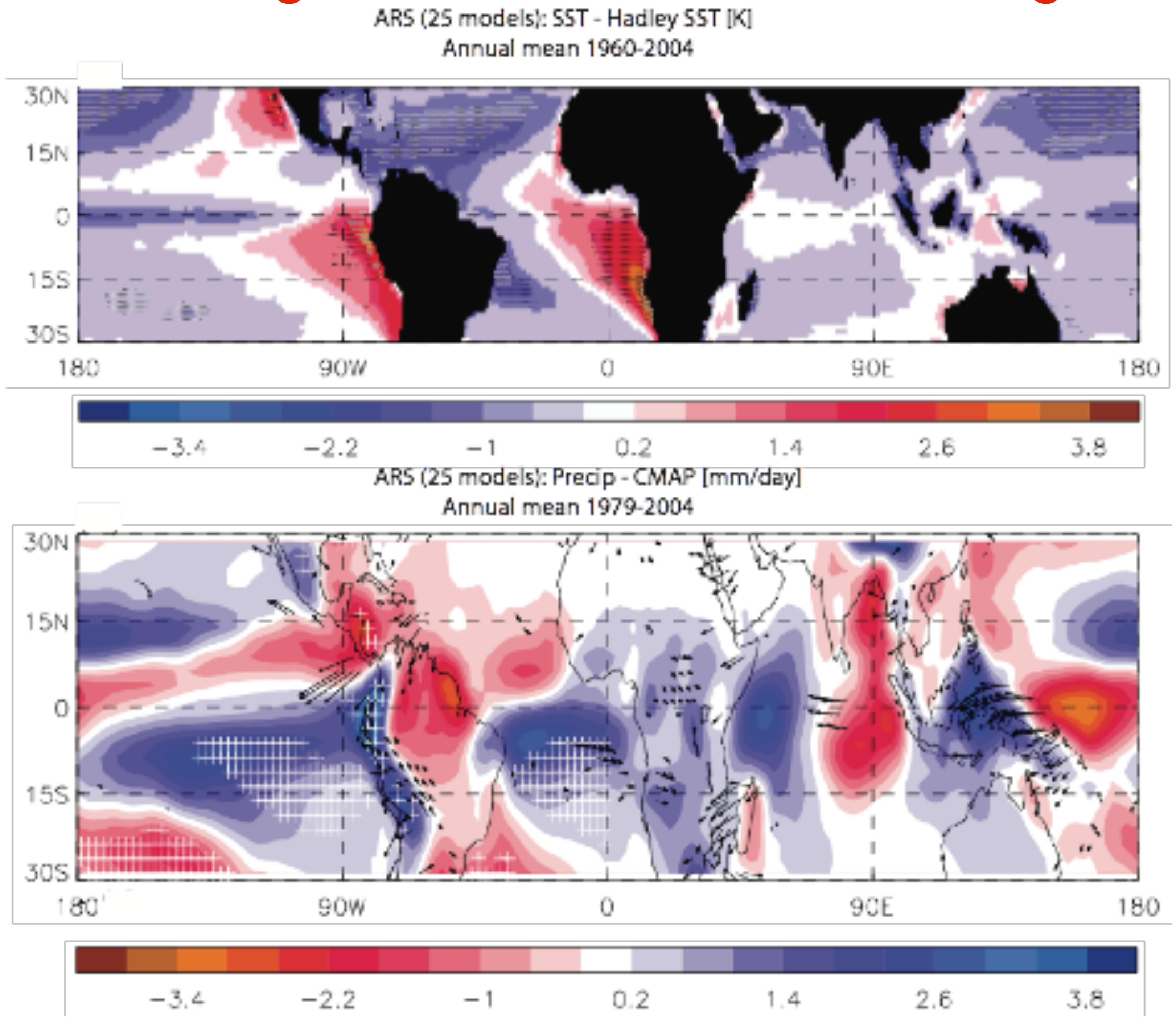
ETOS Working Group Main Page

Documents

Events

ETOS Working Group	
Simon de Szoeke, co-chair	Oregon State University
Roberto Mechoso, co-chair	UCLA
Rob Wood, co-chair	University of Washington
Paquita Zuidema, co-chair	University of Miami
Michela Biasutti	Columbia University/LDEO
Peter Brandt	GEOMAR, Kiel, Germany
Ping Chang	Texas A&M University
Amy Clement	University of Miami
Takeshi Doi	JAMSTEC
Tom Farrar	WHOI
Carmen Grados	IMARPE, Peru
Noel Keenlyside	University of Bergen
Ben Kirtman	University of Miami
Alban Lazar	LOCEAN-IPSL, University Pierre et Marie Curie, France
Brian Medeiros	NCAR
Pierrick Penven	IRD, France
Chris Reason	University of Cape Town, South Africa
Ingo Richter	JAMSTEC
Mathieu Rouault	University of Cape Town, South Africa
Irina Sandu	ECMWF
Ed Schneider	George Mason University/COLA

Eastern tropical SSTs typically too warm in CGCMS, too much southern hemisphere ocean rain, not enough Amazonian/too much Congo rain

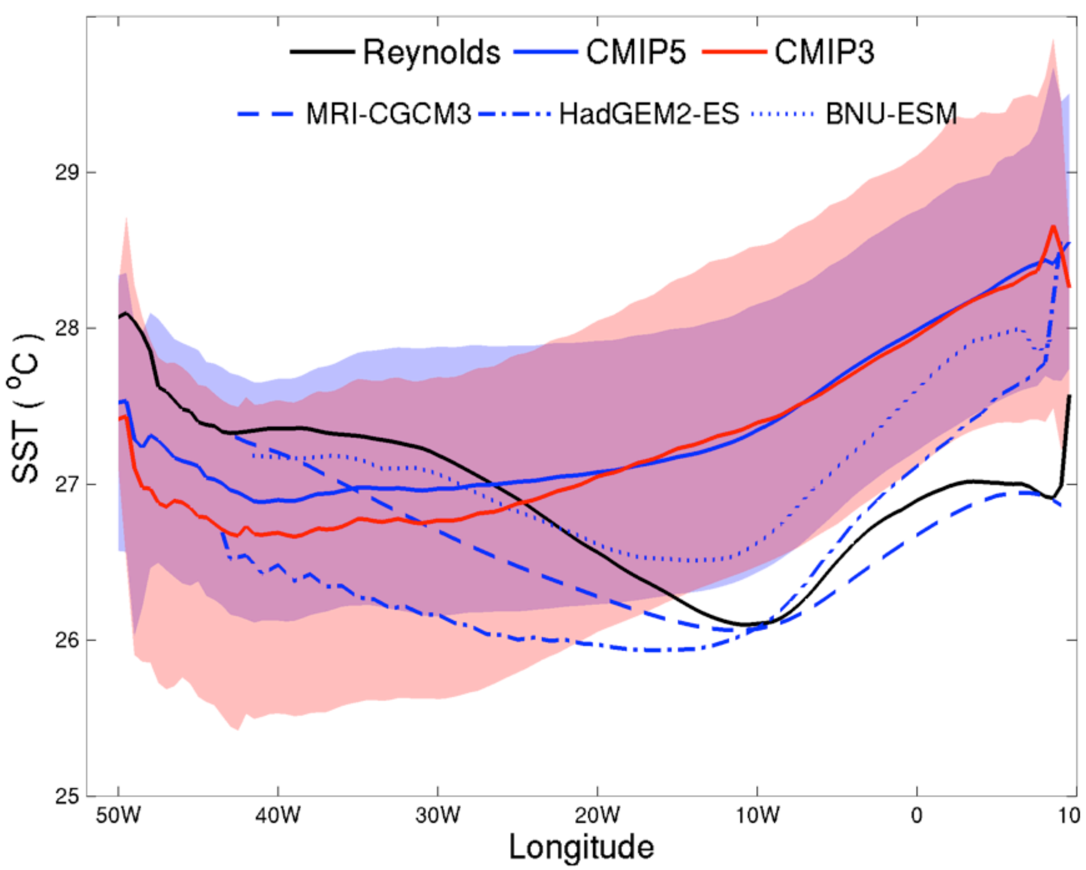


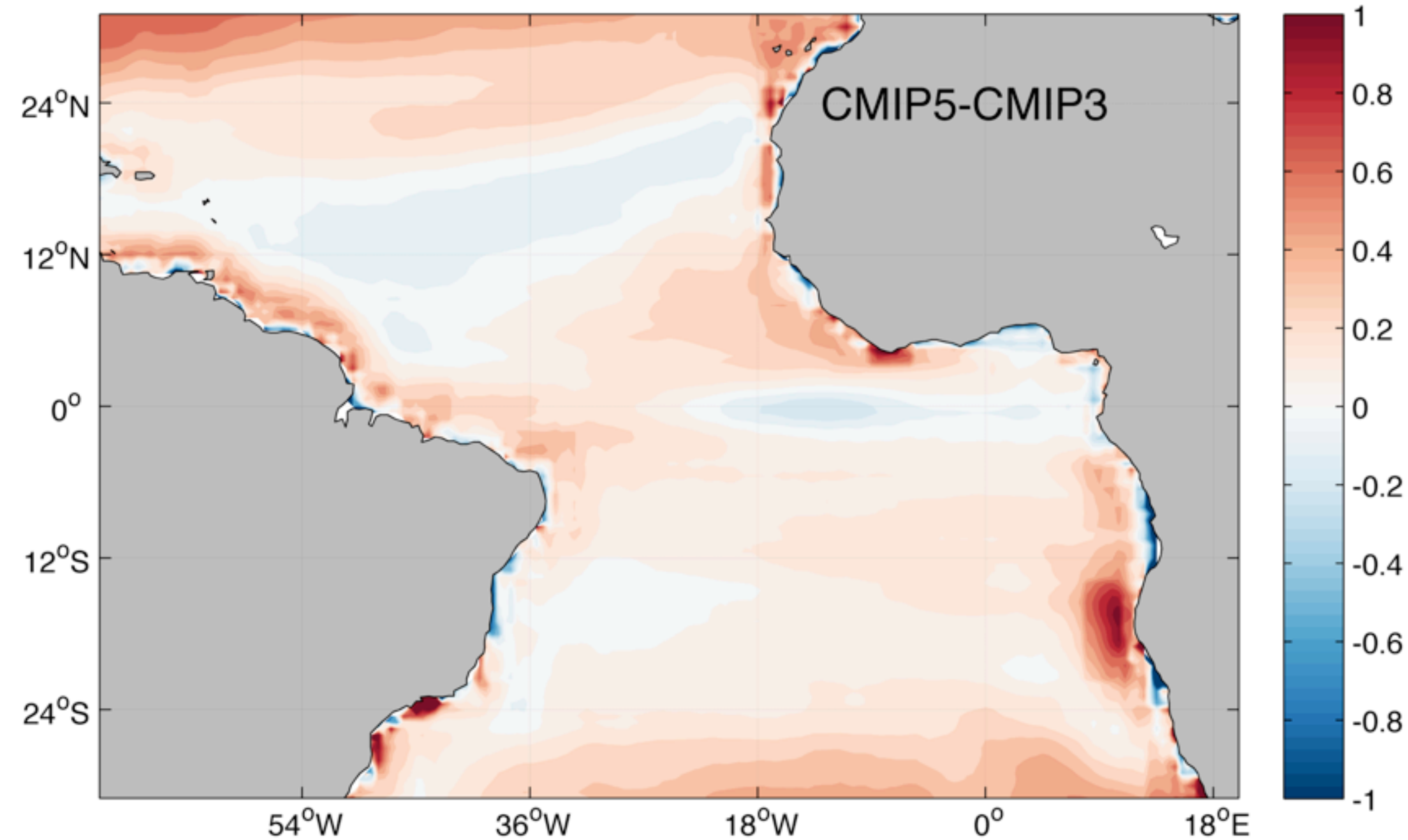
top: mean SST error in historical integrations of 25 coupled CMIP5 GCMs.
bottom: mean precipitation errors relative to CMAP + 10-m wind errors relative to ERA-I

Toniazzo&Woolnough, 2013

CMIP5 models provide only incremental improvement to known Atlantic equatorial SST biases

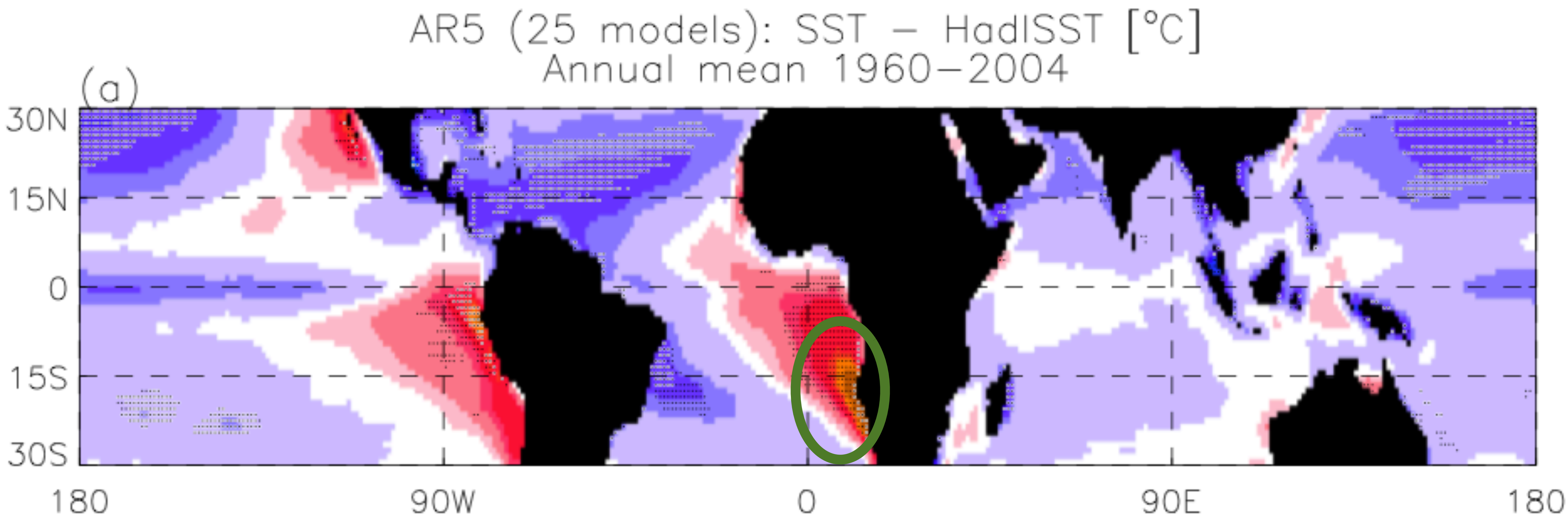
...and the zonal equatorial Atlantic SST gradient remains reversed in CMIP5





Z. Xu/Ping Chang

what may be less appreciated is that the maximum SST bias in the Atlantic occurs in the southeast around 20S, not on the equator



top: mean SST error in historical integrations of 25 coupled CMIP5 GCMs.
bottom: mean precipitation errors relative to CMAP + 10-m wind errors relative to ERA-I

Toniazzo&Woolnough, 2013

model error diagnosis approaches:

- comparison to observations
(have to identify the bias before you can correct it)

- examine initial error tendencies

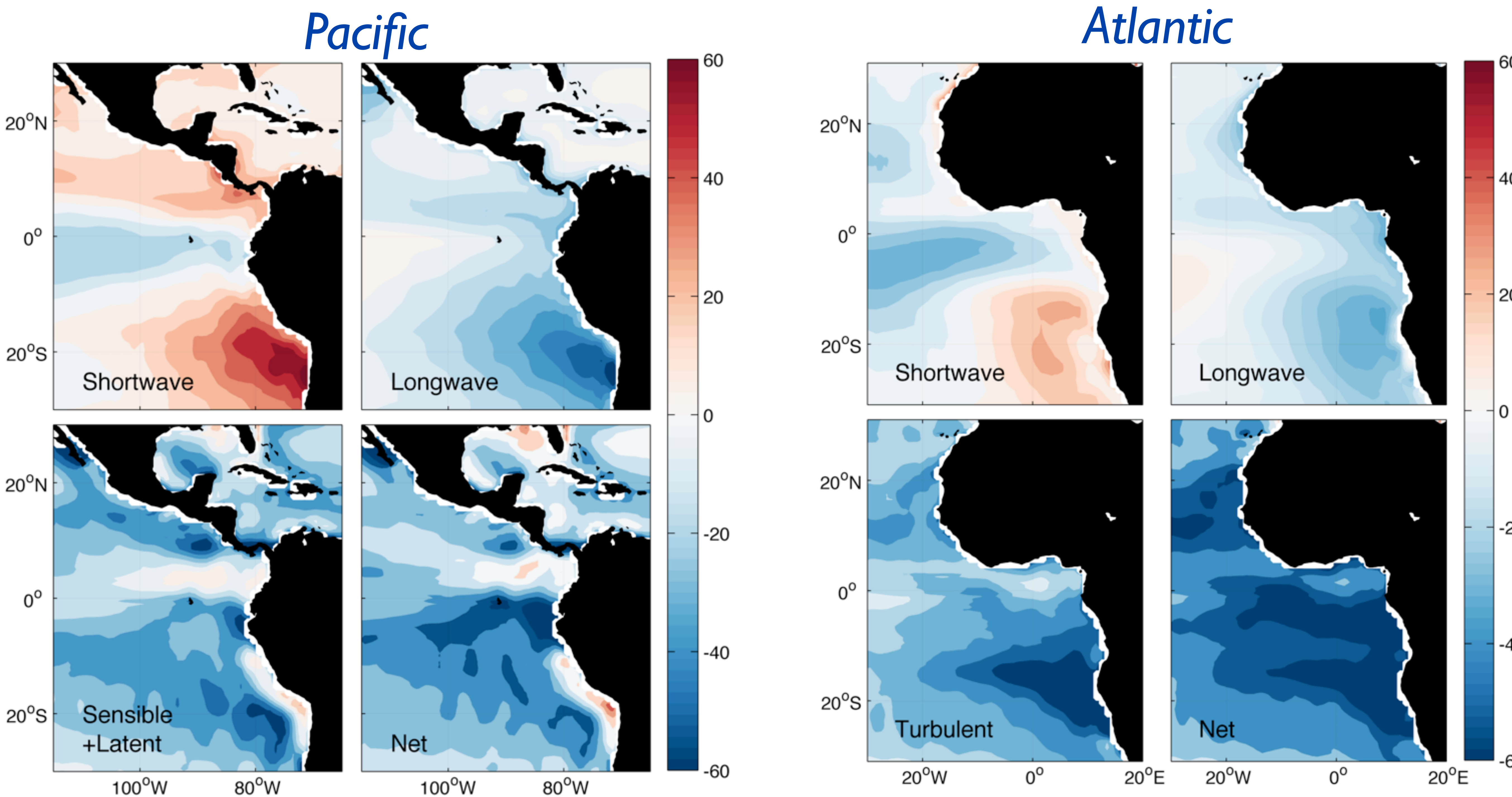
- flux override experiments

structure of the southeast Atlantic and Pacific flux biases differ*

in the Pacific, dominated by the shortwave bias (too little cloud)

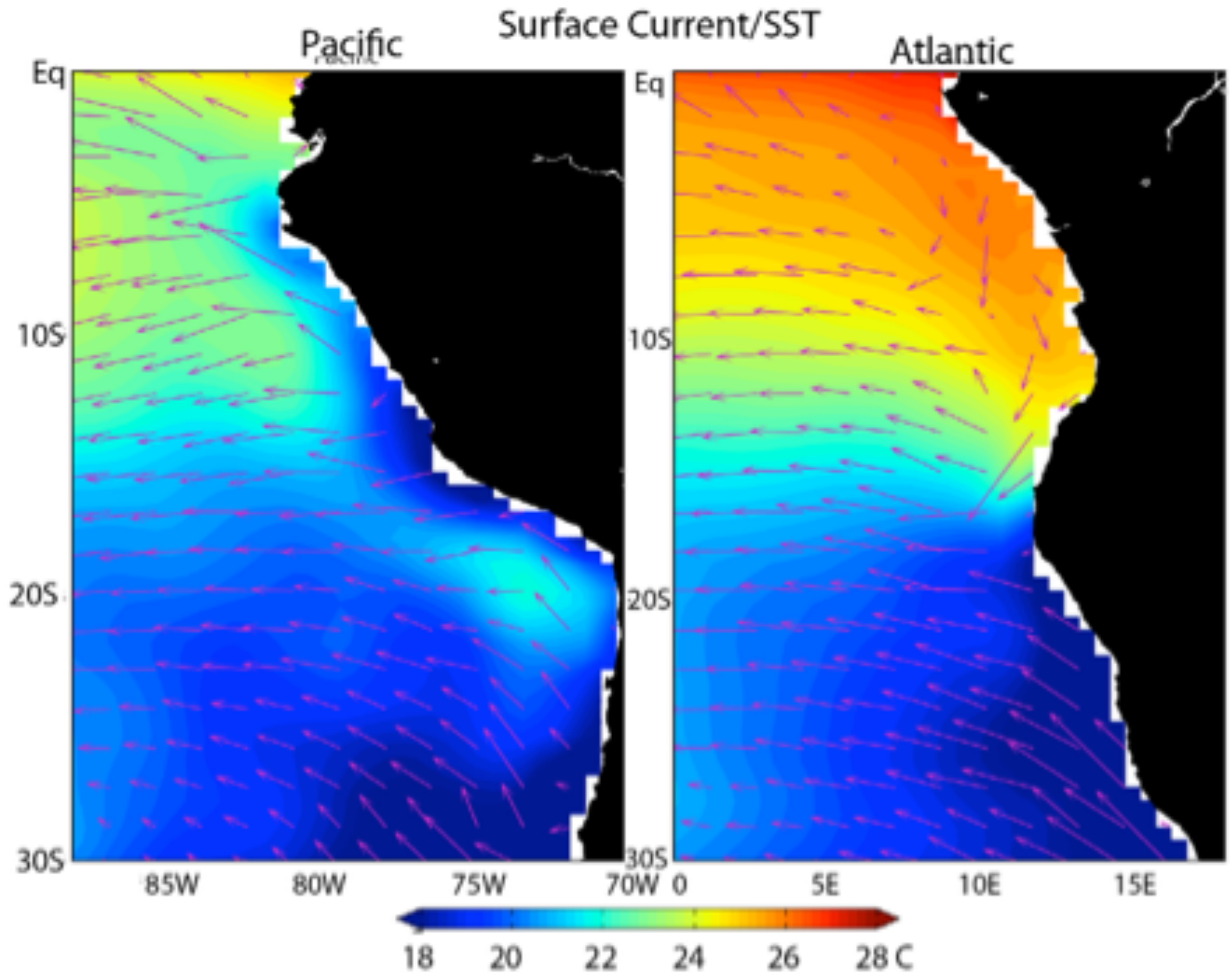
in the Atlantic, dominated by the turbulent fluxes

=> *oceanic contribution to the cooling must be more significant in the Atlantic*

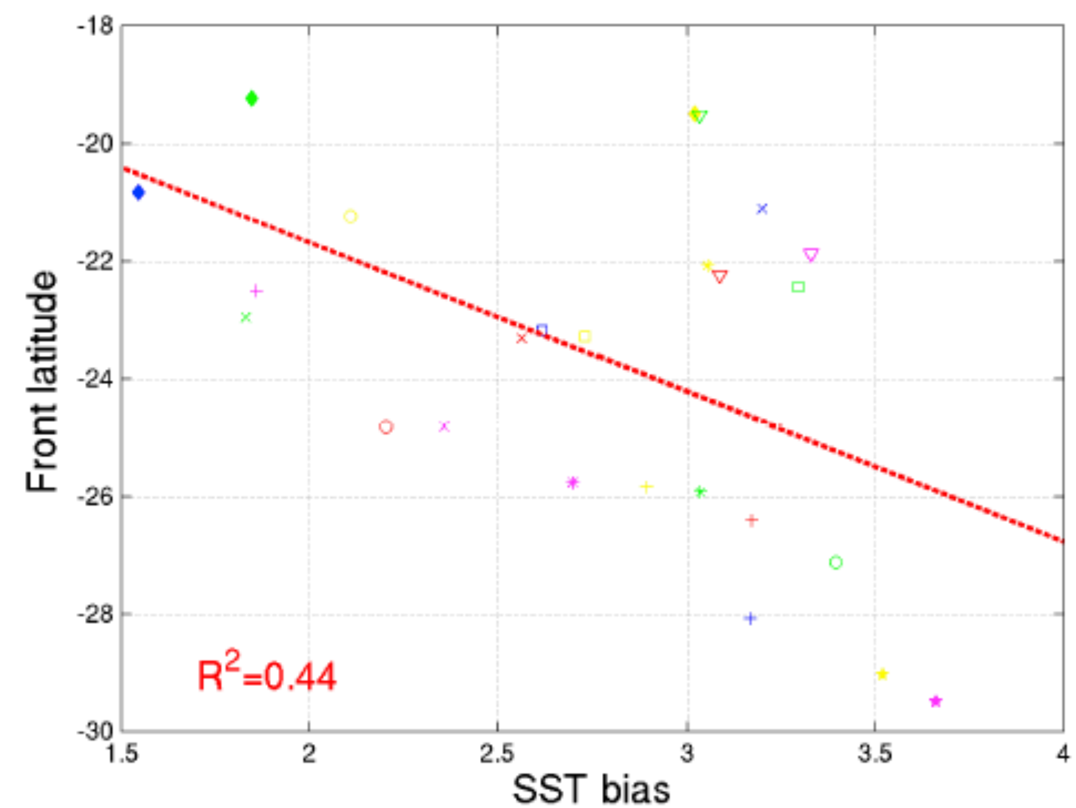


* compared to OAFLUX

this is in line with differences in the ocean climate



SST+surface currents



SEA SST bias enhanced when Angola-Benguela front is displaced too far south in CMIP5 models
Xu et al., 2014

examining initial error growth tendencies:

assesses fast error growth due to parameterization deficiencies before longer-time-scale & remote feedbacks develop that make attribution more difficult

Development of warm SST errors in the southern tropical Atlantic in CMIP5 decadal hindcasts

Thomas Toniazzo · Steve Woolnough

Abstract SST errors in the tropical Atlantic are large and systematic in current coupled general-circulation models. We analyse the growth of these errors in the region of the south-eastern tropical Atlantic in initialised decadal hindcasts integrations for three of the models participating in the Coupled Model Inter-comparison Project 5. A variety of causes for the initial bias development are identified, but a crucial involvement is found, in all cases considered, of ocean-atmosphere coupling for their maintenance. These involve an oceanic "bridge" between the Equator and the Benguela-Angola coastal seas which communicates sub-surface ocean anomalies and constitutes a coupling between SSTs in the south-eastern tropical Atlantic and the winds over the Equator. The resulting coupling between SSTs, winds and precipitation represents a positive feedback for warm SST errors in the south-eastern tropical Atlantic.

Table 1 Models and integrations analysed in this study

Modelling centre	Institute ID	Model name	# of hindcasts used	Ensemble size	Start date
National Centres for Environmental Prediction	NCEP	CFSv2-2011	13	4	1 November
Canadian Centre for Climate Modelling and Analysis	CCCMA	CanCM4	5	10	1 January
Met Office Hadley Centre	MOHC	HadCM3	12	10	1 November

Toniazzo&Woolnough, 2013

most of bias development happened in 2-6 months

initial error causes differed between the 3 models

CFSv2-2011: solar-induced initial error
CanCM4+HadCM3: incorrect winds/precip => boreal-spring amplification

with all three models showing a sustaining oceanic component to the southeast Atlantic biases

NMME phase 2 models lend themselves to such analysis

7 models

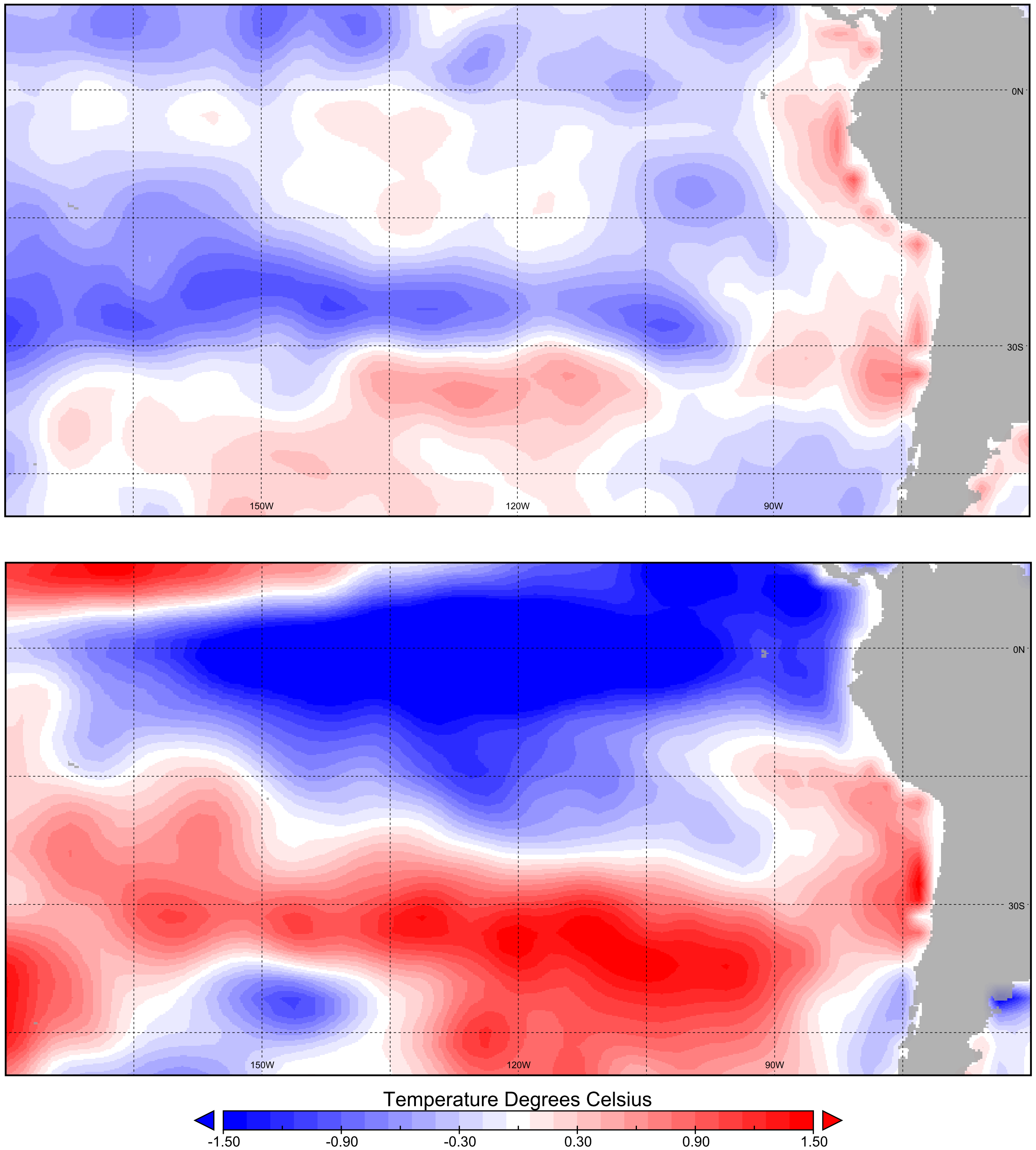
Table 1: NMME Forecast Experiments Phase II.

Model	Hindcast Period	Number of Members	Arrangement of Members	Lead (month)	Model resolution atmosphere	Model resolution ocean	Reference
NCEP/CFSv2	1982-2010	24 (20)	4 members (0, 6, 12, 18z)	0-9	T126L64	MOM4L40 .25deg Eq	Saha et al (2010)
GFDL/CM2.1	1982-2010	10	All 1st of the month 0Z	0-11	2x2.5degL24	MOM4L50 .3deg Eq	Delworth (2006)
CMC1-CanCM3	1981-2010	10	All 1st of the month 0Z	0-11	CanAM3 T63L31	CanOM4L40 .94deg Eq	Merryfield et al. (2012)
CMC-CanCM4.5	1982-present	20	All 1st of the month 0Z	0-11	CanAM4 T63L35	OPA/ORCA1 1x.33deg L46 Eq	Merryfield et al. (2012)
NCAR/CCSM4	1982-2010	10	All 1st of the month 0Z	0-11	0.9x1.25degL26	POPL60 .25deg Eq	
NCAR/CESM1	1982-2010	6	All 1st of the month 0Z	0-11	0.9x1.25degL30	POPL60 .25deg Eq	
NASA/GEOS5	1981-2010	11	4 members every 5th days; 7 members on the last day of last month	0-9	1x1.25 deg L72	MOM4L40 .25deg Eq	Rienecker et al. (2008)

Kirtman et al., 2013

- *daily data on air-sea fluxes, precip, clouds, ocean+atmosphere state*
- *forecasts made near beginning of each month; seasonal variation in error growth provides insight into the mechanism (e.g., in Pacific a westerly wind bias leading to a basin-wide SST bias is most active in boreal winter*

example: NMME/CCSM4 ensemble mean SST error, initialized 0Z Dec 27 of years 1982-2009



averaged over first 5 days

averaged over days 361-365

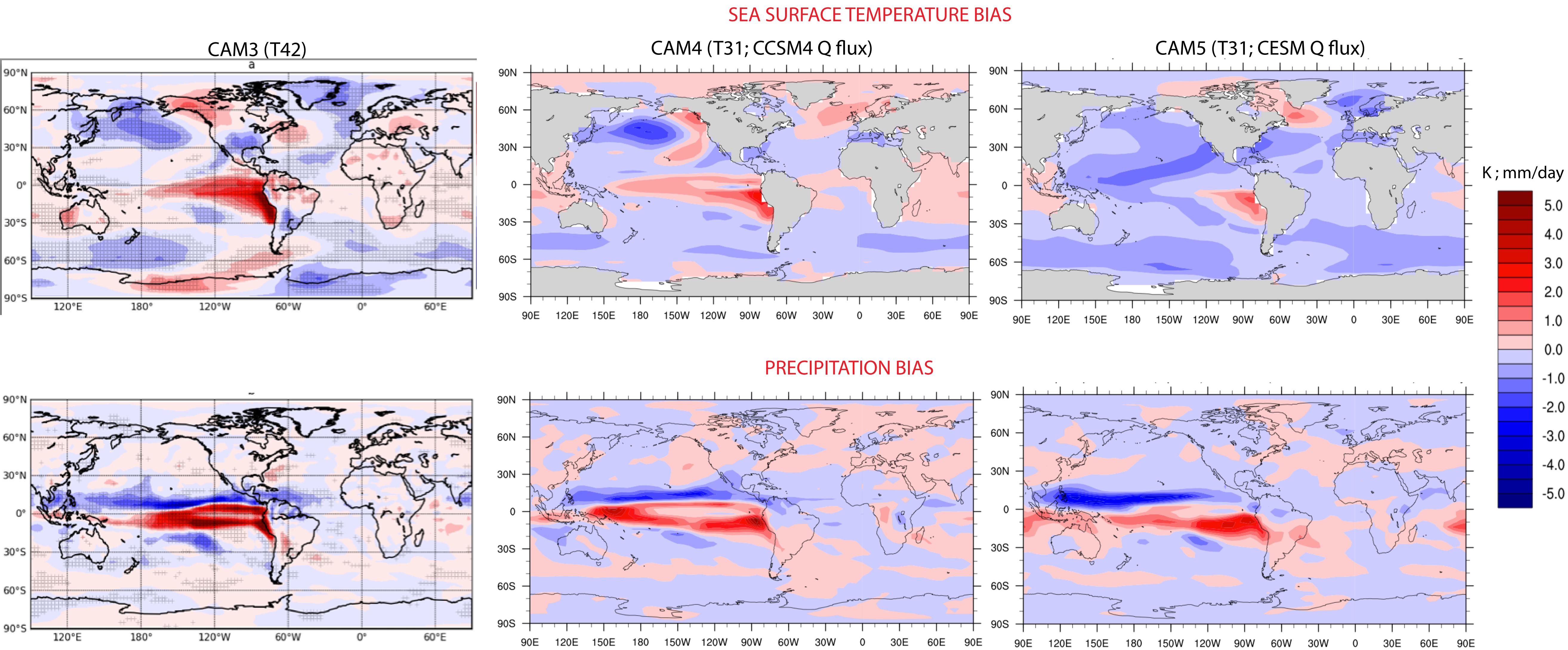
warm bias already apparent after 5 days *another diagnostic technique: flux-override experiments*

- impose observed fluxes/winds in a specific region
- remove & allow full coupling to re-establish
- evaluate for error growth

flux overrides have been done to assess remote impacts of the SEP/SEA biases

experiment: internal heat flux reduced to zero in the southeast Pacific (5-30S, 70-135W) & redistributed elsewhere, in 3 models

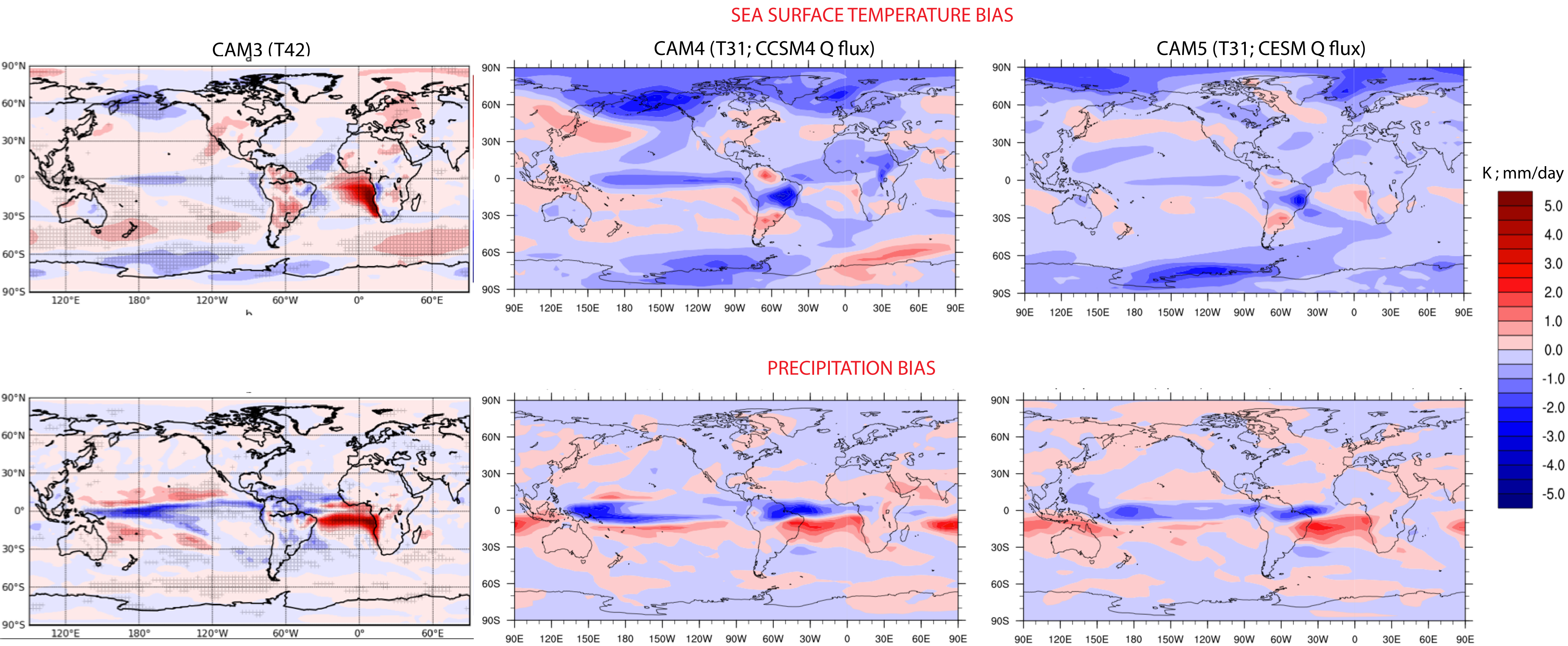
in this case demonstrates a southward ITCZ shift in the Pacific (but not the Atlantic)



adopted from Xu et al., 2014; Ed Schneider

similar but weaker changes in CAM4/CAM5 reflects difference reference datasets

similar experiment in the Atlantic demonstrates a southward shift in both Atlantic and Pacific basins



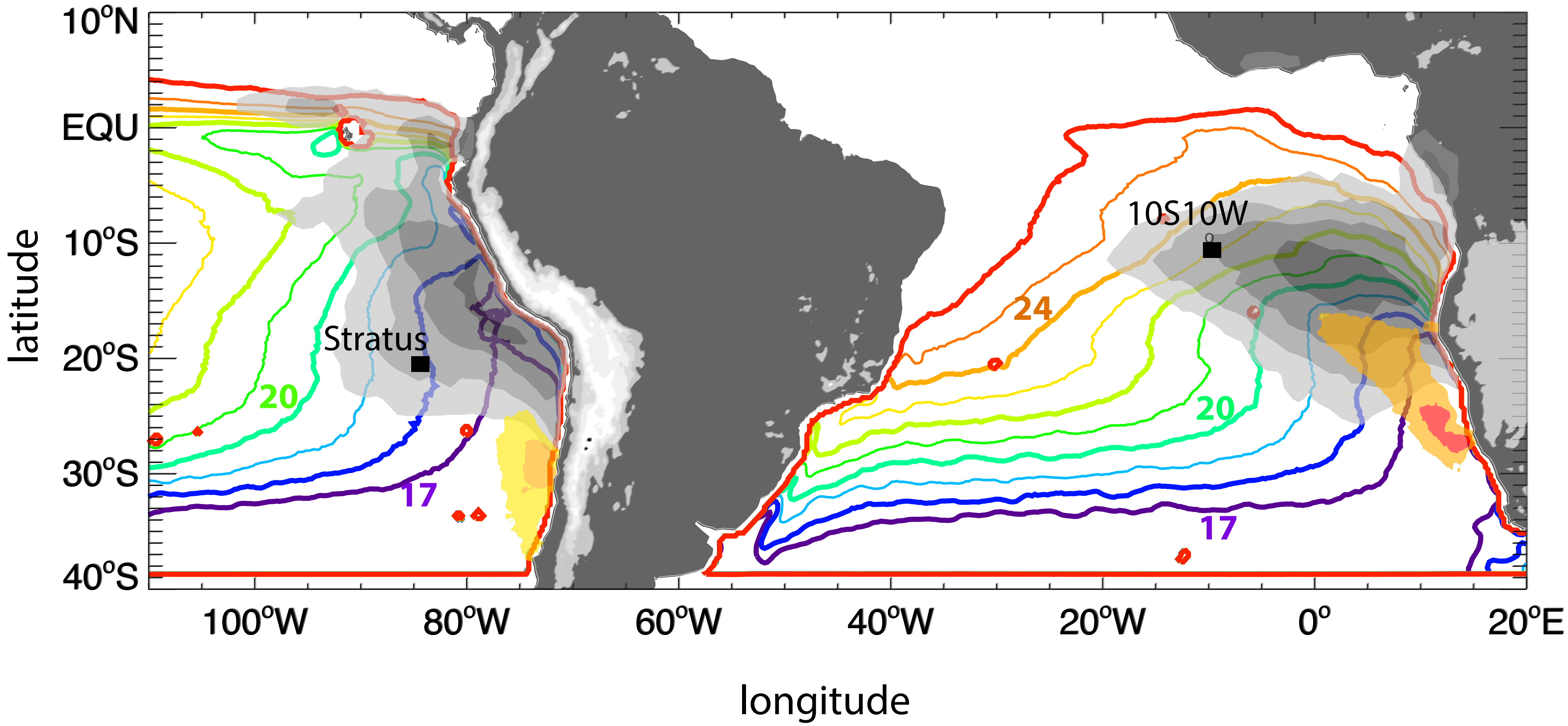
bias correction depends on how the bias is determined

initialization system dataset also ideal for model evaluation

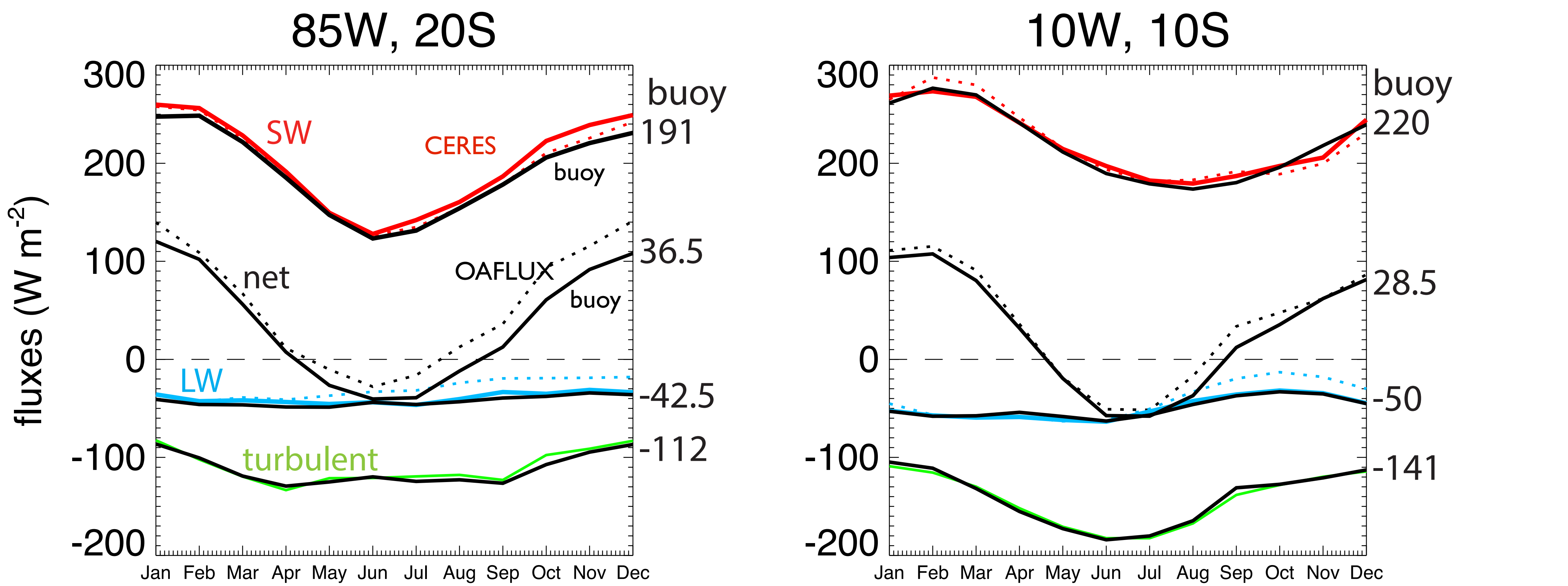
model-independent datasets also useful

surface flux products assessed at two 'full-flux' buoy sites

September-mean TMI SST, MODIS cloud fraction, QuikScat coastal wind maxima climatology



color contours - SST; filled grey contours - MODIS cloud fraction 0.6-0.9;
filled color contours - coastal surface wind jets 7-9 m/s



thick black lines - buoy *red+blue solid - CERES* *red+blue dashed - ISCCP* *green-OAFLUX*

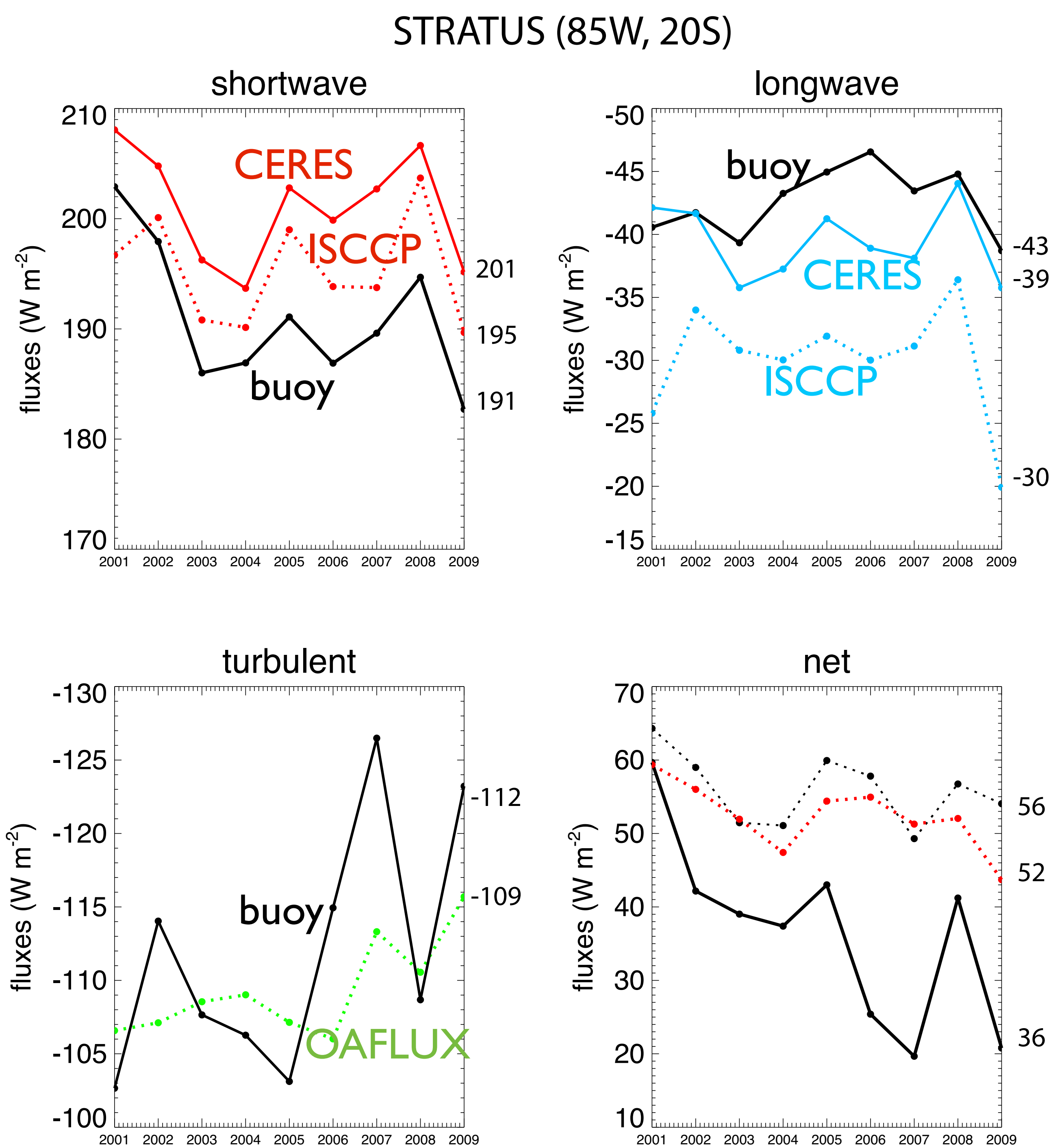
	net SW W m-2	net LW W m-2	SH+LH W m-2	net
buoy	191.0	-42.6	-111.9	36.5
CERES	201.1	-39.4		
OAFLUX (ISCCP)	195.3	-30.0	-109.3	56.0

January 1, 2001-December 31, 2009

OAFLUX overestimates the amount of heat entering the ocean by almost 20 W m-2, because of errors in ISCCP SW+LW surface products
=> model bias is actually even worse

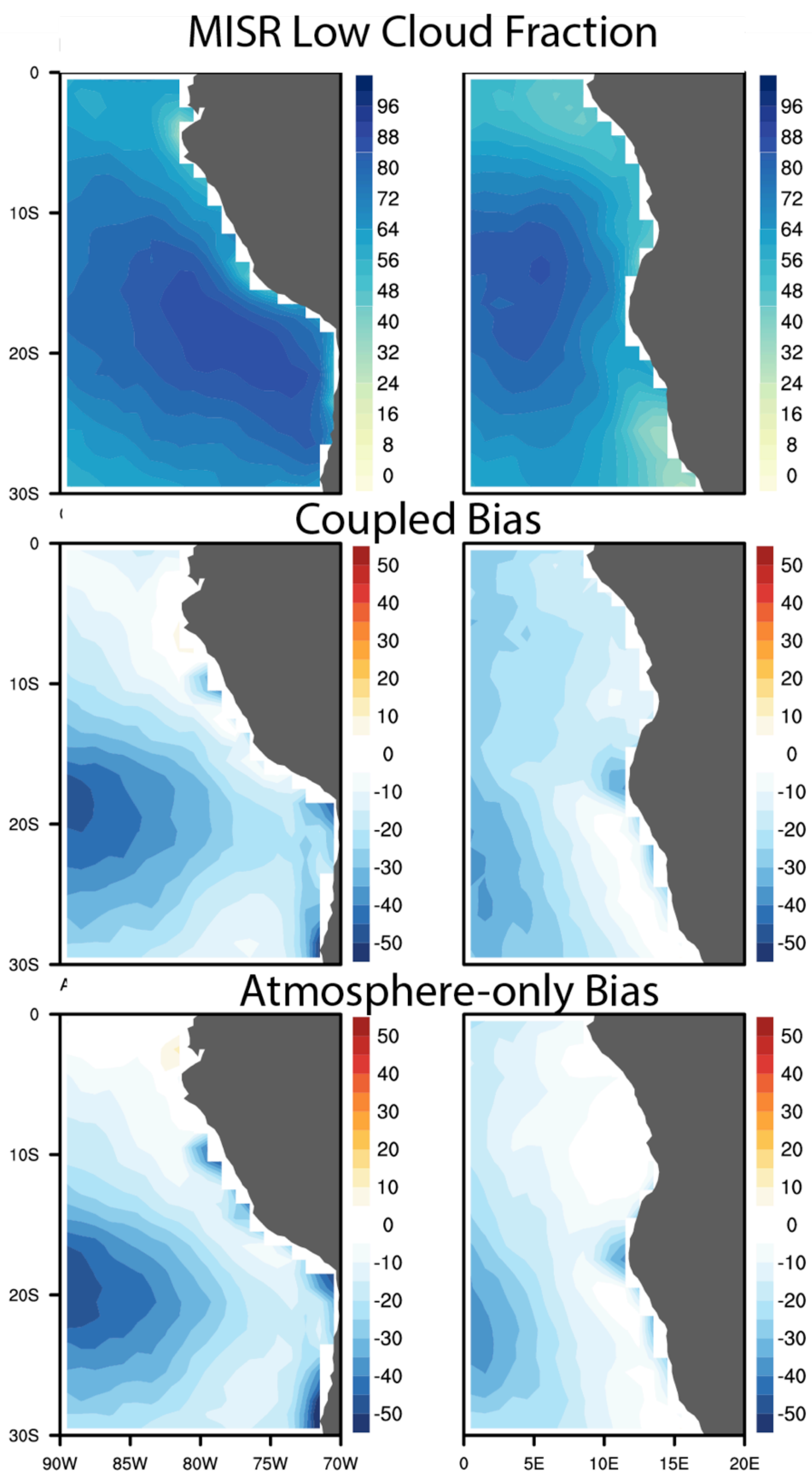
CERES SW worse, but LW better, than ISCCP

do OAFLUX/CERES fluxes capture observed interannual variability?



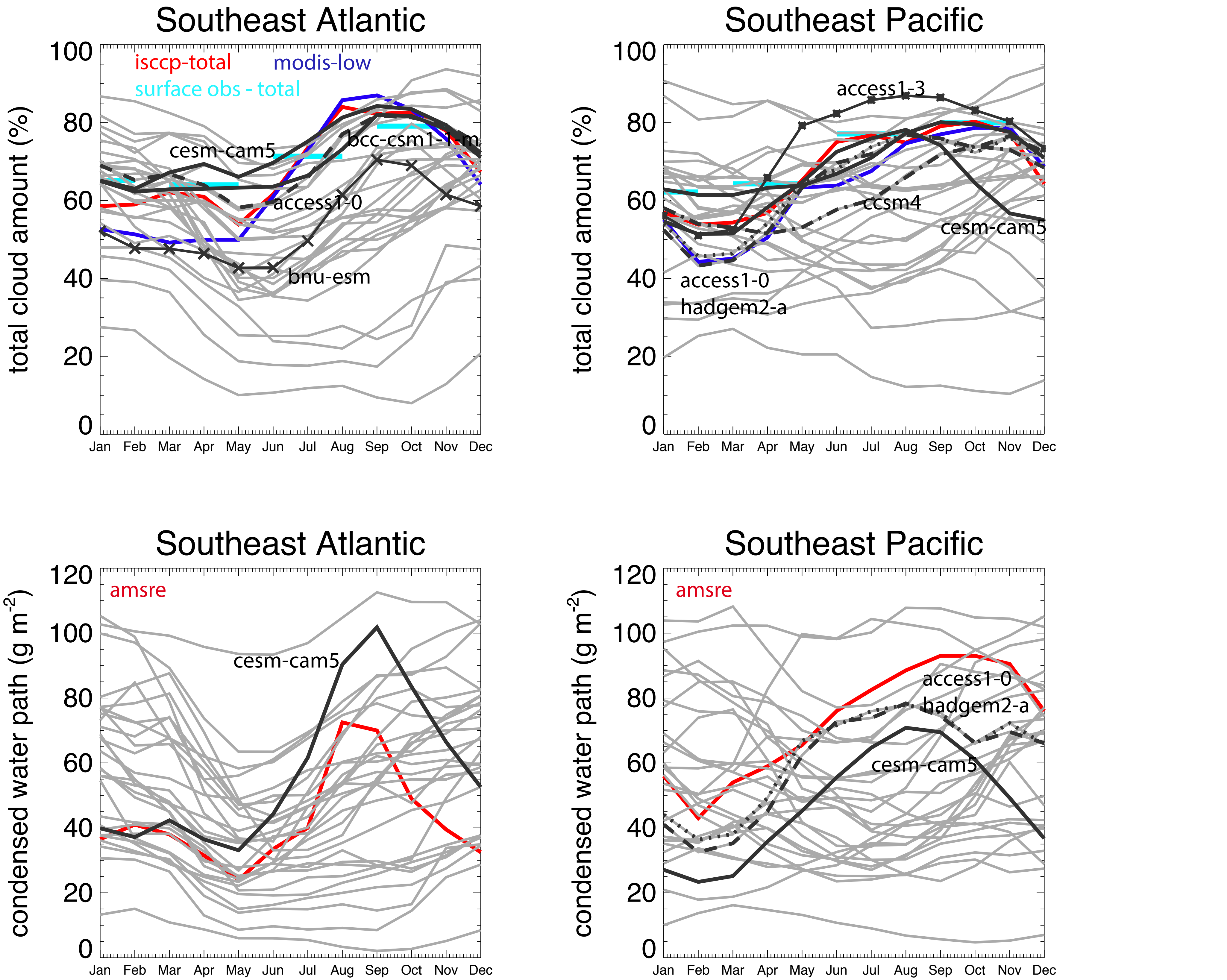
so-so...SW yes, other components, no

low cloud errors assessed independently against MISR



low cloud errors occur independently of underlying SST, pointing to parameterizations at fault

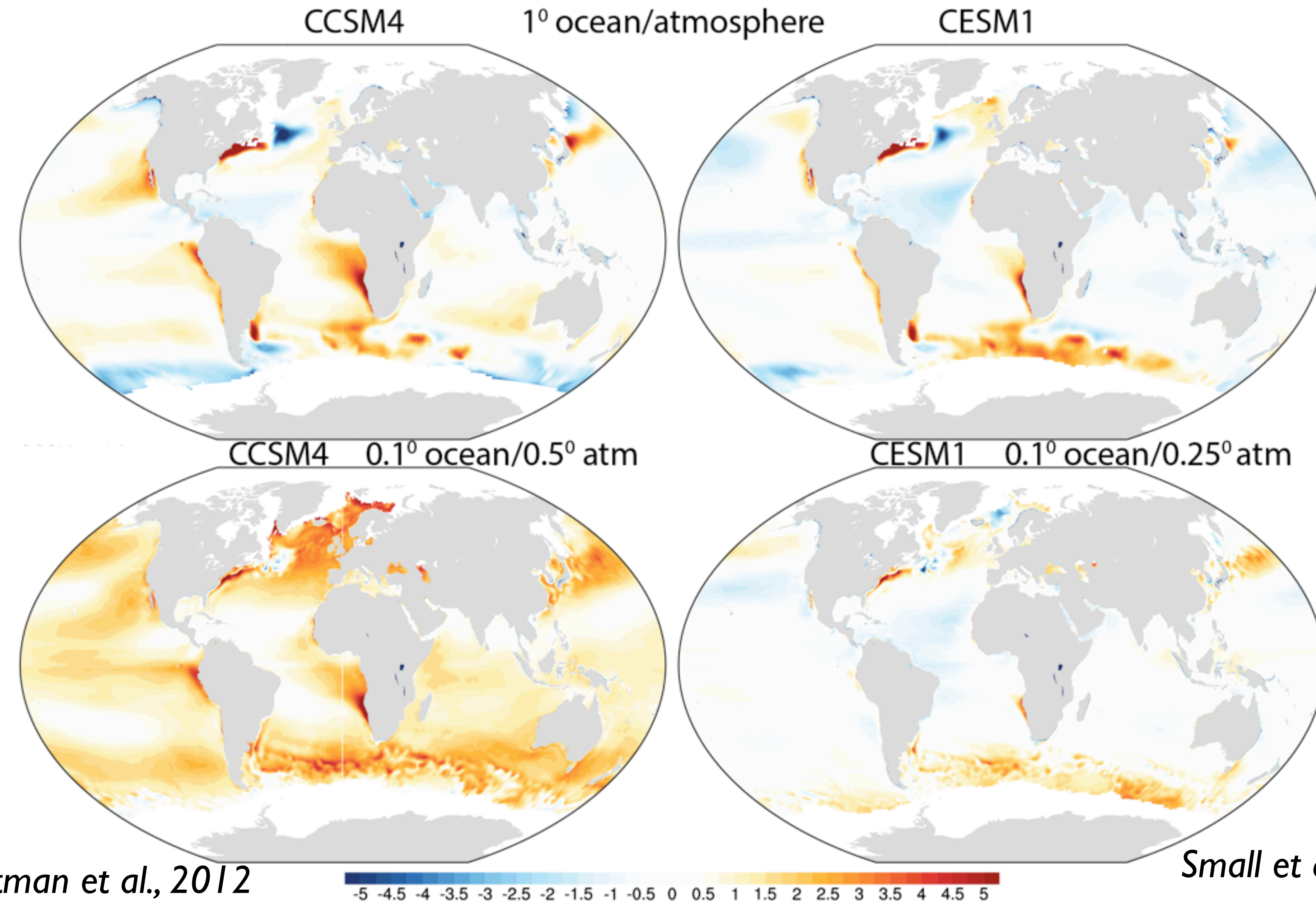
widely-varying seasonal cycles in CMIP5 low clouds vs observed



Katinka Bellomo

should correspond with differences in initial error growth causes

does increasing resolution reduces the SST biases?



Kirtman et al., 2012

Small et al., 2015

not necessarily: in CESM1, improvement in SEA (stronger upwelling) may be for wrong reason, how POP2 ocean model incorporates atmosphere winds

in CCSM4, a too diffuse thermocline is even more diffuse at higher resolution the end